Chapter - 8

SUMMARY,

CONCLUSION AND

RECOMMENDATIONS
Chapter - 8. Summary, Conclusion and Recommendations

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CHAPTER 8

Summary, Conclusion and Recommendations

An experimental analysis for machining-induced delaminations associated with machining parameters on various natural fibers reinforced plastic (NFRP) composites and on two different fiber orientations (0° and 90°) is presented in this study.

As seen in this research, the Taguchi orthogonal design of experiment method provides a systematic and efficient methodology for the design optimization of the machining parameters resulting in the minimum peel up delamination, push down delamination, milling induced delamination, average surface roughness, and maximum tensile strength in two different fiber orientation (0° and 90°) natural fiber reinforced plastic (NFRP) composites with far less effect than would be required for most optimization approaches.

From the analysis of results in machined NFRP composite laminates using conceptual Signal-to-Noise (S/N) ratio approach and analysis of variance (ANOVA), the following can be concluded from the present study within the range of the experiments.

8.1. Conclusions for Drilling-Induced Delaminations (Fd):

(1) From the Figs. (5.5 - 5.12 and 5.23 - 5.30), the quality of the hole (drilling induced delamination) produced in the natural fiber reinforced plastic (NFRP) composites tested is found to be better when compared with the corresponding quality of glass fiber reinforced plastics (GFRP) composites. The quality of the drilled natural fiber reinforced plastic composites at high speed (32 m/min) and low feed (0.1 mm/rev) is
found to be better than those of glass fiber reinforced plastic composites. This suggest that natural fiber reinforced plastic composites have a potential to replace synthetic fiber composites in many applications where machining is needed.

(2) The Hemp Fiber Reinforced Plastics (HFRP) is found to promote less damage than the other natural fiber reinforced plastic composites, i.e., the delamination factor (\(F_d\)) is smaller as evident from the Figs. (5.5 - 5.12 and 5.23 - 5.30).

(3) Based on the Signal-to-Noise (S/N) ratio analysis, the optimal parameters for the delamination factor are the feed rate at level 1 (0.1 mm/rev) and the cutting speed at level 3 (32 m/min).

(4) Based on the ANOVA analysis, it is observed that the cutting speed has shown 25% higher influence on the peel up delamination than feed rate. But for pushdown delamination the feed rate has shown 30% higher influence than the cutting speed.

(5) From Figs. (5.59 - 5.66), it is found that the cutting speed and feed rate parameters influence the delaminations. Therefore, the cutting speed and feed rate seems to be the most critical parameters and should be selected carefully in order to reduce all kinds of damages.

(6) From tables (5.1 - 5.4 and 5.19 - 5.22), it is found that the 0° orientation NFRPs promotes less delamination values in drilling process when compared with 90° orientation NFRPs.

**8.2. Conclusions for Tensile Strength (TS) of Drilled NFRPs:**

(1) Based on the Signal-to-Noise (S/N) ratio analysis, the optimal machining parameters for the tensile strength are the cutting speed at level 2 (24 m/min) and feed rate at level 1 (0.1 mm/rev).
(2) From tables (5.39 and 5.48), it can be concluded that the drilling induced damage at higher cutting speeds severely affects the tensile strength ($T_s$) of drilled NFRPs.

(3) The amount of damage extent has not shown any appreciable influence on the tensile strength of the drilled Natural Fiber Reinforced Plastics.

(4) From the Figs. (5.41 - 5.44 and 5.50 - 5.53), drilling at medium cutting speed is found to be higher tensile strength ($T_s$) in both $0^0$ and $90^0$ orientation Natural Fiber Reinforced Plastics.

(5) Based on the ANOVA analysis, it is observed that the cutting speed has shown 20% higher influence on the tensile strength ($T_s$) than feed rate.

(6) From tables (5.37 and 5.46), it is found that the $0^0$ orientation Natural Fiber Reinforced Plastics promote more tensile strength than the $90^0$ orientation Natural Fiber Reinforced Plastics.

8.3. Conclusions for Milling-Induced Delaminations ($F_d$):

(1) From the Figs. (6.5 – 6.8 and 6.14 - 6.17), the quality of the slots (milling induced delamination) produced in the natural fiber reinforced plastic (NFRP) composites tested is also found to be better when compared with the corresponding quality of glass fiber reinforced plastic (GFRP) composites. The quality of the milled NFRPs at high speed (32 m/min) and low feed (0.1 mm/rev) is found to be better than those of glass fiber reinforced plastic composites.

(2) The Hemp Fiber Reinforced Plastic (HFRP) composite is found to promote less damage than the other natural fiber reinforced plastic composites, i.e., the milling-induced induced delamination factor ($F_d$) is smaller as evident from the Figs. (6.5 – 6.8 and 6.14 - 6.17).
(3) Based on the Signal-to-Noise (S/N) ratio analysis, the optimal parameters for the milling-induced delamination factor \((F_d)\) are the feed rate at level 1 (0.1 mm/rev) and the cutting speed at level 3 (32 m/min).

(4) Based on the ANOVA analysis, it is observed that the feed rate has shown 30% higher influence on the milling-induced delamination factor \((F_d)\) than cutting speed.

(5) From Figs. (6.41 – 6.44), it is found that the feed rate and cutting speed parameters influence the milling-induced delaminations. Therefore, the cutting speed and feed rate seems to be the most critical parameters and should be selected carefully in order to reduce all kinds of damages in milling NFRPs.

(6) From tables (6.1 and 6.10), it is found that the 0° orientation NFRPs promotes less delamination values in milling process when compared with 90° orientation NFRPs.

**8.4. Conclusions for Average Surface roughness \((R_a)\) of Milled NFRPs:**

(1) From the Figs. (6.23 – 6.26 and 6.32 - 6.35), the surface roughness of the milled NFRPs at high speed (32 m/min) and low feed (0.1 mm/rev) is found to be better than those of glass fiber reinforced plastic composites.

(2) From tables (6.22 and 6.31), milling at low feed rate is found to be lesser surface roughness \((R_a)\) in both 0° and 90° orientation Natural Fiber Reinforced Plastics.

(3) Based on the Signal-to-Noise (S/N) ratio analysis, the optimal machining parameters for the milling-induced surface roughness are the cutting speed at level 3 (32 m/min) and feed rate at level 1 (0.1 mm/rev).

(4) Based on the ANOVA analysis, it is observed that the feed rate has shown 35% higher influence on the milling-induced surface roughness \((R_a)\) than cutting speed.
(5) From Figs. (6.44 - 6.48), it is found that the cutting speed and feed rate parameters influence the milling-induced delaminations. Therefore, the cutting speed and feed rate seems to be the most critical parameters and should be selected carefully in order to obtain good surface finish in milling NFRPs.

(6) From tables (6.19 and 6.28), it is found that the $0^0$ orientation NFRPs promotes less surface roughness values in milling process when compared with $90^0$ orientation NFRPs.

8.5. Conclusions for Machine Vision Parameters:

From the results of the machine vision experiments for determining delamination and surface roughness of the machined fiber reinforced plastic composites; the following can be concluded from the present study within the range of the experiments.

(1) Two new machine vision parameters (Delamination area and Co-efficient of Variance) were introduced for determining the delaminations and surface roughness of the machined natural fiber reinforced composites.

(2) In tables (7.1 – 7.4), it is found that the delamination and roughness of the surfaces conclusively affect the vision parameters.

(3) The machine vision parameters are having good correlation with microscope measured delamination factor ($F_d$) and stylus measured surface roughness ($R_a$).

8.6. Scope for Future Work:

(1) Identifying and introducing the new natural fibers and natural fiber reinforced plastic composites which is having good machinability.
(2) To study the effect of various types of matrix phases and fiber surface modifications on machining induced damages and on final performances of the machined natural fiber reinforced composites.

(3) To identify the behavior of natural fiber reinforced composites for other machining processes like trimming, grinding, turning etc.

8.6. Recommendations:

(1) It is better to machine (both drilling and milling) the fiber reinforced plastic composites at low feed rate (0.1 mm/rev) and at high cutting speed (32 m/min) to obtain the minimum machining damages (delamination and surface roughness) with maximum tensile strength.

(2) To determine the Delamination and Surface Roughness using Machine Vision, it is recommended to use separate regression equation for each coloured materials.